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Research Article

Influence of different establishment method, varieties and nitrogen level on productivity and economics of rice

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ABSTRACT
A field experiment was conducted to determine the productivity and economics of rice influenced by crop establishment methods, varieties and nitrogen levels on growth, phenology and yield of rice cultivars in the sub-tropical climate of Chitwan, Nepal. Three factors Strip-split plot experimental design using establishment methods (conservation and conventional agriculture) in vertical plots; varieties (hybrid Gorakhnath 509 and high yielding Sabitri) in horizontal plots and four nitrogen levels (0, 60, 120 and 180 kg N ha^{-1}) in sub-sub plots was laid out with three replications. The research result revealed that, grain yield of rice along with nitrogen use efficiencies, net return and B:C ratio was significantly higher in conservation agriculture than conventional agriculture. The higher grain yield in CA plots was because of higher number of effective tillers per square meter as compared to conventional agriculture. The grain yield of both hybrid and high yielding varieties were statistically similar whereas nitrogen level of 180 kg ha^{-1} produced the highest grain yield which was statistically similar to 120 kg ha^{-1} N but significantly higher than 60 kg ha^{-1} N. Higher N application increased the effective tillers per square meter and number of grains per panicle which resulted in higher grain yield. Net return and B:C ratio were higher at 120 and 180 kg ha^{-1} N applied plots. Thus for sustainable rice production, conservation agriculture with high yielding variety and nitrogen level of 120 kg ha^{-1} are best.
Keywords: Conservation agriculture, conventional agriculture, nitrogen levels, effective tillers

INTRODUCTION
Rice rank as a first crop in terms of area coverage and productivity in Nepal. It occupies 56.42% of cultivated land with a productivity of 3.50 t ha-1 (MOAD, 2076) and constitutes 13.85 % of agricultural gross domestic product (MOF Economic Survey, 2016) overcoming more than 50% of Nepalese calorie requirement (Basnet, 2014).

In rice planting, two methods are common i.e. conventional and conservation tillage. The conventional method is prevalent in Nepal which is done through transplanting in the puddled fields. In the conventional method, puddling of the soil is the main operation that benefits by reducing water percolation losses, controlling weeds, facilitating easy seedling establishment, and creating anaerobic conditions to enhance nutrient availability (Sanchez, 1973). However, it encounters several problems such as labor-intensive, high water requirement for puddling, and negative impact on soil physical, chemical, and microbial properties which increase the cost of cultivation with a potential loss in farm income. Repeated puddling develop hardpan in the subsoil below the puddled layer (Giri, 1988) which restricts the growth and productivity of succeeding wheat crop (Sharma, Ladha & Bhusan, 2003). Moreover, methane emission is higher in transplanted rice fields than in direct seeding (Kumar & Ladha, 2011). Also, nitrogen leaching is more severe in flooded rice, heavy application of nitrogen in flooded rice causes emerging problems of deficiency of micronutrients such as zinc and secondary nutrients such as sulfur (Sakal, 1977). Further, intensive tillage systems result in decreased soil organic matter and biodiversity (Biamah et al., 2000). As only 52.08% of the total cultivated area is irrigated in Nepal (MOAC, 2016) farmers are forced to monsoon dependent transplanting operations in Nepal cause the shift in cropping calendar and impact on yield.

On contrary, conservation agriculture (CA) has emerged as a promising technique in rice cultivation through decreasing the water demand by omitting the puddling operation and conserving the soil. Conservation agriculture is based on the principles of resource conservation, through minimum tillage, optimum residue retention, and proper crop rotation (Sayre & Hobbs, 2004). CA practices increase water storage, reduce water loss and erosion, improve crop yield and water productivity, and labor use (Xiaobin, 2006), increase soil organic matter (Rasmussen, 1999), increase carbon sequestration (Uri et al., 1999), and produce yield equivalent to or higher than those under conventional farming (Karunatilake, Vanes & Schindelbeck, 2000; Guerif, Richard, Durr, Machet, Recous & Roger-Estrade, 2001). However, a major problem that limits the CA are Apart high weed infestation (Joshi, Kumar, Lal, Nepalia, Gautam & Vyas, 2013), poor seed germination, and reduced early seedling growth (Qi, Nie, Liu, Peng, Shah, Huang, Cui & Sun, 2012) and high nitrogen loss through denitrification, volatilization, leaching, and runoff as compared to conventional agriculture (Kumar & Ladha, 2011; Davidson, 1991).

Apart from the establishment methods, nitrogen has a significant role in the productivity of rice. Only a part of applied nitrogen is used by plants and the remaining residual is accumulated in soil or lost as runoff (Khan & Mohammad, 2014). The synchronization between crop demand and nitrogen supply is the most important aspect of increasing nitrogen fertilizer use efficiency, high yields, and reduced nitrogen losses. Levels of nitrogen required especially vary among the varieties either hybrid, improved or local. A real-time N management requires periodic assessment of nitrogen status in standing crops and applying the optimum nitrogen dose to reduce its loss. Adhikari (2006) stated that low nitrogen use efficiency in the ineffective splitting of N application including the use of nitrogen in excess of the requirement is one of the various factors responsible for lower rice production (Adhikari, 2006).

Nitrogen demand differs with inbred and hybrid varieties. Hybrid technology allows farmers to obtain 15-30% more rice than conventional high-yielding varieties (Siddiq, 1993; Virmani, Mao & Hardy, 2003). Viramani (1996) reported that hybrid rice required different strategies for N management to maximize the expression of their yield advantage. The country’s target is to achieve over 5 million tons of rice production by the year 2020 to be food sufficient (Joshy, 1997). The labor problem is increasing and forming being uneconomic. Effective nitrogen management and improved package of practices play an important role in the increasing response to added nitrogen and thereby improving the grain yield of high-yielding varieties including hybrids. Considering these facts experiment was conducted to be acquainted with the level of nitrogen best suitable for the rice cultivars under different cultivation practices.

MATERIALS AND METHODS

The experiment was carried out at the agronomy block of Agriculture and Forestry University Rampur, Chitwan in sandy loam soil with a moderately acidic pH of 5.93. Total nitrogen and soil available potassium was found to be lower (0.15% and 116.85 kg ha^{-1}) in surface soil profile but soil available phosphorous was found to be of medium (27.45 kg ha^{-1}) and most of all parameters were found decreasing with increasing profile depth up to 1m. Weather data regarding minimum and maximum temperature, relative humidity, and rainfall were collected from the National Climatic Observatory of National Maize Research Program, Rampur, Chitwan. Three-factor Strip-split design was used as an experimental design with establishment method as a horizontal factor, varieties as a vertical factor, and nitrogen levels as subplot factor. Establishment methods include conservation agriculture (zero tillage with residue) and conventional tillage (P-TPR), varieties include hybrid Gorakhnath 509 and improved Sabitri, and nitrogen levels were 0, 60, 120, and 180 kg N ha-1. For the conventional method, nursery raising was done and transplanting was done with 21 days old seedlings. 2-3 seedlings per hill with hill spacing of 20cm row to row and plant to plant was maintained during transplanting. Urea, diammonium phosphate, muriate of potash, and single super phosphate were used as sources of fertilizer. As per the government recommendation, 30:30 PK kg ha-1 fertilizer was used except the nitrogen which was used as per the treatment. The full dose of Phosphorous and potassium were broadcasted as basal dose and nitrogen was applied at three splits: half at basal, one fourth at active tillering, and one fourth at the panicle initiation stage. In CA, rice was sown continuously in mechanically drawn rows spaced 20cm apart. Fertilizer was applied as a side dressing in the basal application and broadcasted at the top dressing. Observation on yield and yield attributes were recorded and analyzed through MSTAT-C software. The experiment was carried out at the agronomy block of Agriculture and Forestry University Rampur, Chitwan in sandy loam soil with a moderately acidic pH of 5.93. Total nitrogen and soil available potassium was found to be lower (0.15% and 116.85 kg ha-1) in surface soil profile but soil available phosphorous was found to be of medium (27.45 kg ha-1) and most of all parameters were found decreasing with increasing profile depth up to 1m. Weather data regarding minimum and maximum temperature, relative humidity, and rainfall were collected from the National Climatic Observatory of National Maize Research Program, Rampur, Chitwan. Three-factor Strip-split design was used as an experimental design with establishment method as a horizontal factor, varieties as a vertical factor, and nitrogen levels as subplot factor. Establishment methods include conservation agriculture (zero tillage with residue) and conventional tillage (P-TPR), varieties include hybrid Gorakhnath 509 and improved Sabitri and nitrogen levels were 0, 60, 120, and 180 kg N ha-1. For the conventional method, nursery raising was done and transplanting was done with 21 days old seedlings. 2-3 seedlings per hill with hill spacing of 20cm row to row and plant to plant was maintained during transplanting. Urea, diammonium phosphate, muriate of potash and single super phosphate were used as sources of fertilizer. As per the government recommendation, 30:30 PK kg ha^{-1} fertilizer was used except the nitrogen which was used as per the treatment. The full dose of Phosphorous and potassium were broadcasted as basal dose and nitrogen were applied at three splits: half at basal, one fourth at active tillering, and one fourth at the panicle initiation stage. In CA, rice was sown continuously in mechanically drawn rows spaced 20cm apart. Fertilizer was applied as a side dressing in the basal application and broadcasted at top dressing. Observation on yield and yield attributes were recorded and analyzed through MSTAT-C software.

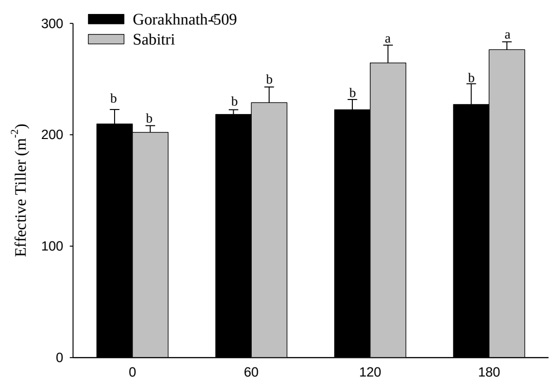
RESULTS AND DISCUSSION

Yield attributing characters

In the experiment, effective tillers were significantly differed due to nitrogen levels and establishment methods only. Effective tillers per meter were found significantly higher in conservation agriculture (261.10) than conventional agriculture (201.30). The result was in line with Hobbs, Singh, Giri, Lauren & Duxbury (2002). This was due to the close spacing causing a higher plant population (Patil et al., 2007) which increases the mother plant causing less effect due to tiller mortality. Fageria (2014) reported that in the aerobic condition the effective tillers in the main culm are important than other secondary tillers. In conservation agriculture seeds are shown continuously in rows resulting in more number of the main culm which is limiting in TPR due to wider spacing. An increase in nitrogen level increased the effective tillers per meter. Effective tillers per meter in 180 kg N ha^{-1} (251.80) was at par with 120 kg N ha-1 (243.50) but was significantly higher than 60 kg N ha-1. The lowest effective tillers were observed in nitrogen a control plot (205.90) which was similar to 60kg N ha-1. Thakur and Singh (1987) also reported significantly higher effective tillers per square meter and spikelets per panicle in higher nitrogen levels.

Interaction of varieties and nitrogen levels significantly influenced the effective tillers (Figure 1). Gorkhanath-509 have statistically similar effective tillers per square meter for all nitrogen levels whereas Sabitri showed significantly higher tillers in 180 kg N ha^{-1} as compared to 60 and 0 kg N ha^{-1} and was at par with 120 kg N ha^{-1}.

Figure 1: Effective tillers (m^{-2}) of rice as influenced by interaction between varieties and nitrogen level in 2015 at AFU, Rampur, Chitwan, Nepal



Note: Treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance

Grains per panicle were found higher in conventional agriculture (137.70) than conservation agriculture (122.80). Gorakhnath-509 had statistically higher grains per panicle (158.90) as compared to Sabitri (101.60). Grains per panicle was found highest in 120 kg N ha^{-1} (136.10) which was significantly at par with 180 (135.00) and 60 kg N ha^{-1} (129.60). Nitrogen control was found to have lowest grain yield (120.10). Similar results was obtained by Maqsood (1998). In grain filling stage, nitrogen contributes to grains (Swain & Jagpat, 2010) which helps to decrease the sterility and increase grains per panicle.

Thousand grain weight was found significantly higher in conventional agriculture (17.80 g) than conservation agriculture (17.67 g). In direct seeded rice, increase effective tillers per square meter increases intra plant competition which decrease the size of grains. Similarly, Sabitri (20.65 g) have higher thousand grain weight than Gorakhnath-509 (14.82 g). It resulted due to fine grains of Gorakhanath-509 than Sabitri. The significant difference between varieties was due to their genotypic character as Gorakhnath 509 is a fine grain cultivar whereas Sabitri is coarse grain as compared to Gorakhnath 509. Significant difference was not observed in thousand grain weight due to nitrogen levels. Similar, result was obtained by Patil, et al (2001).

Table 1: Influence of establishment methods, varieties and nitrogen levels on Yield attributes of rice during monsoon season at Rampur, Chitwan, Nepal, 2015

Treatment	Effective tillers (m^{-2})	Grains per panicle	Thousand grain weight (g)
Establishment method			
CA	261.10^{a}	122.80^{b}	17.67^{b}
Con A	201.30^{b}	137.70^{a}	17.80^{a}
SEm (±)	9.27	1.58	0.02
LSD (=0.05)	56.40	9.62	0.102
Varieties			
Gorakhnath-509	219.40	158.90^{a}	14.82^{b}
Sabitri	242.90	101.60^{b}	20.65^{a}
SEm (±)	8.85	5.82	0.26
LSD (=0.05)	Ns	35.44	1.592
Nitrogen levels (kg ha^{-1})			
0	205.90^{c}	120.10^{b}	17.98
60	223.50^{bc}	129.60^{ab}	17.77
120	343.40^{ab}	136.10^{a}	17.64
180	251.80^{a}	135.00^{a}	17.55
SEm (±)	7.24	4.14	0.23
LSD (=0.05)	21.13	12.08	Ns
CV, %	10.80	11.00	4.40
Grand mean	231.20	130.20	17.74

Note: CA, Conservation agriculture; ConA, conventional agriculture; ns, non-significance. Treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance

Yield

The grain yield of conservation agriculture (4766 kg ha^{-1}) was statistically higher than conventional agriculture (4106 kg ha^{-1}) (Table 2). It was due to the sum effect of leaf area index and effective tillers. CA increases yield by improving soil fertility through soil and water conservation and sequestering organic carbon (Holland, 2004; Govaerts et al., 2007). Varieties didn't have any significant influence on yield. It was due to the similar yield potential of both varieties. In the case of nitrogen levels, the grain yield at 180 kg N ha^{-1} was statistically similar with the grain yield (4769 kg ha^{-1}) at 120 kg N ha^{-1} but significantly higher than grain yield at 60 kg N ha^{-1} (4308kg ha^{-1}) and 0 kg N ha^{-1} (3686 kg ha^{-1}). Manzoor et al (2006) also reported similar results. The numbers of tillers and spikelets are increased by increased nitrogen content (Matsushima, 1976) which ultimately increases the yield.

The straw yield was significantly higher in conventional agriculture (5648 kg ha ha^{-1}) as compared to conventional agriculture (4487 kg ha ha^{-1}). Similarly, in the case of variety, Sabitri had a significantly higher (5683 kg ha ha^{-1}) straw yield as compared to Gorakhnath-509 (4451 kg ha^{-1}). The average straw yield was found to be 5067 kg ha^{-1}. In the case of nitrogen, straw yield at 180 kg N ha^{-1} (5896 kg ha^{-1}) was significantly at par with 120 kg N ha-1 (5792 kg ha^{-1}) which was statistically higher than 0 (4041 kg ha^{-1}) and 60 kg N ha^{-1} (5540 kg ha^{-1}). Straw yield results from the total biomass which increased due to higher effective tillers per square meter in CA. Fageria (2014) stated that higher nitrogen application helps in protein metabolism and ultimately carbohydrate metabolism in the latter stages of growth which might be the cause of higher total above-ground biomass.

Table 2: Influence of establishment methods, varieties and nitrogen levels on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) of rice during monsoon season at Rampur, Chitwan, Nepal, 2015

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Establishment methods		
CA	4766.00^{a}	5648.00^{a}
ConA	4106.00^{b}	4487.00^{b}
SEm (±)	35.60	62.7
LSD (=0.05)	216.50	381.5
Varieties		
Gorakhnath	4438.00	4451.00^{b}
Sabitri	4433.00	5683.00^{a}
SEm (±)	172.80	183.70
LSD (=0.05)	ns	1117.50
Nitrogen levels (kg ha^{-1})		
0	3686.00^{c}	4041.00^{b}
60	4308.00^{b}	4540.00^{b}
120	4769.00^{a}	5792.00^{a}
180	4980.00^{a}	5896.00^{a}
SEm (±)	91.00	268.40
LSD (=0.05)	265.70	783.30
CV, %	7.10	18.30
Grand mean	4436.00	5067.00

Note: CA, Conservation agriculture; ConA, conventional agriculture; ns, non-significance. Treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance

Economic Analysis

The total cost of production in conservation agriculture was lower (80.94 thousand NRs ha^{-1}) than that of conventional tillage (84.10 thousand NRs ha^{-1}). In comparison between varieties, the cost was 23.33% higher in Gorakhnath 509 than in Sabitri. The higher cost of Gorakhnath 509 was due to the higher cost of hybrid seeds than improved. In the case of nitrogen level, it was highest in 0 kg N ha^{-1} (86.13 thousand NRs ha^{-1}) as followed by 180 (83.92 thousand NRs ha^{-1}), 120 (81.68 thousand NRs ha^{-1}), and 60 kg N ha ha^{-1} (80.94 thousand NRs ha^{-1}).

Gross return was significantly higher in conservation agriculture by 17% as compared to conventional tillage. Nitrogen level showed increasing gross return with increasing the dose of nitrogen. The highest gross return was obtained at 180 kg N ha^{-1} (143.47 thousand NRs ha 1) which was statistically at par with 120 kg N ha^{-1} (137.01 thousand NRs ha^{-1}) but significantly higher than 60 kg N ha^{-1} (122.94 thousand NRs ha^{-1}) and nitrogen omitted plots (106.42 thousand NRs ha^{-1}). The net return also showed a similar trend to the gross return. It was found significantly higher in conservation agriculture (56.76 thousand NRs ha^{-1}) as compared to conventional tillage (32.23 thousand NRs ha^{-1}). Net return increased with an increase in the dose of nitrogen due to increased production. The highest net return was obtained at 180 kg N ha^{-1} (60.35 thousand NRs ha^{-1}) which was statistically at par with 120 kg N ha-1 (55.33 thousand NRs ha^{-1}) but significantly higher than 60 kg N ha^{-1} (42.00 thousand NRs ha^{-1}) and nitrogen omitted plots (20.29 thousand NRs ha^{-1}).

Table 3: Influence of establishment methods, varieties and nitrogen levels on Cost of cultivation (thousand NRs. ha^{-1}), gross returns (thousand NRs. ha^{-1}), net returns (thousand NRs. ha^{-1}) and B:C ratio of rice during monsoon season at Rampur, Chitwan, Nepal, 2015

Treatments	Total production cost ('000)	Gross Returns ('000)	Net Returns ('000)	B:C ratio
Establishment methods				
CA	80.94	137.69^{a}	56.76^{a}	1.73^{a}
ConA	84.10	117.22^{b}	32.23^{b}	1.40^{b}
SEm(±)		0.89	0.89	0.01
LSD (=0.05)		5.42	5.44	0.06
Varieties				
Gorakhnath	91.97	121.19	29.22	1.32^{b}
Sabitri	73.97	133.74	59.77	1.81^{a}
SEm(±)		5.10	5.10	0.06
LSD (=0.05)		ns	ns	0.35
Nitrogen levels (kg ha^{-1})				
0	86.13	106.42^{c}	20.29^{c}	1.25^{c}
60	80.94	122.94^{b}	42.00^{c}	1.55^{b}
120	81.68	137.01^{a}	55.33^{a}	1.72^{a}
180	83.12	143.47^{a}	60.35^{a}	1.76^{a}
SEm(±)		3.61	3.61	0.04
LSD (=0.05)		10.54	10.54	0.13
CV, %		12.75	44.49	1.57
Grand mean		9.80	28.10	9.80

B:C ratio was significantly influenced by all treatments (establishment methods, varieties and nitrogen levels) (table 3). B:C was found to be significantly higher in conservation agriculture (1.73) as compared to conventional tillage (1.40). In case of varieties, Gorakhnath 509 had lower (1.32) B:C than Sabitri (1.81). Nitrogen level showed increasing B:C with increasing the dose of nitrogen. Highest net return was obtained at 180 kg N ha^{-1} (1.76) which was statistically at par with 120 kg N ha^{-1} (1.72) but significantly higher than 60 kg N ha^{-1} (1.55) and nitrogen omitted plots (1.25).

Kumar & Ladha (2011) conducted economic analysis of of rice establishment practices and concluded that US $ 9– 125 ha^{-1} reductions on the cost of production in ZT-DSR compared with puddled-TPR. IRRI (2009) also recorded higher net return in ZT-DSR in many experiment conducted in different states of India. These cost reductions and increased income were largely due to either reduced labor cost or tillage cost or both under DSR systems. The higher cost of cultivation in N omitted plots may be due to the result of need of high amount of SSP.

CONCLUSION

Rice in humid subtropics can be successfully grown under conservation agriculture and have a chance to harvest more yield, improving profit along with saving the cost of cultivation. Improve variety Sabitri yielded similar to the popular hybrid. Hybrid requires more nitrogen as compared to improve Sabitri and the requirement is even more under conservation agriculture. Application of 120 kg N ha^{-1} was seemed to have better yielding and economic return as at par with 180 kg N ha^{-1}.

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